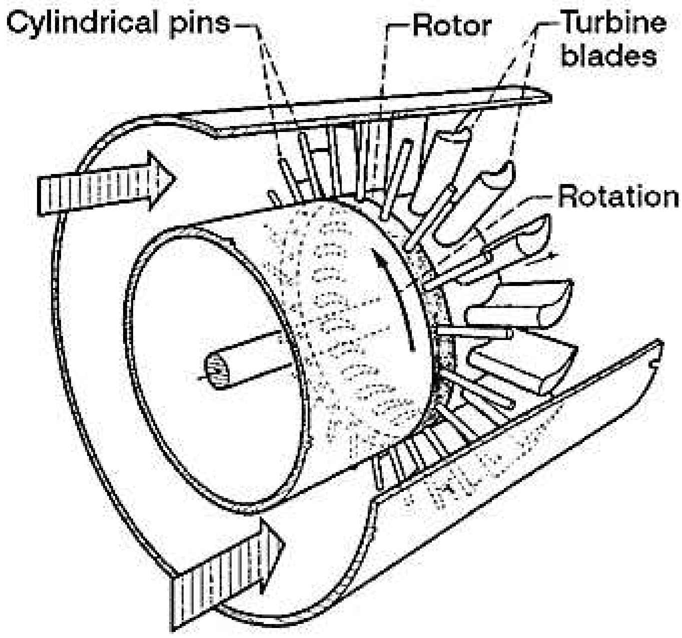
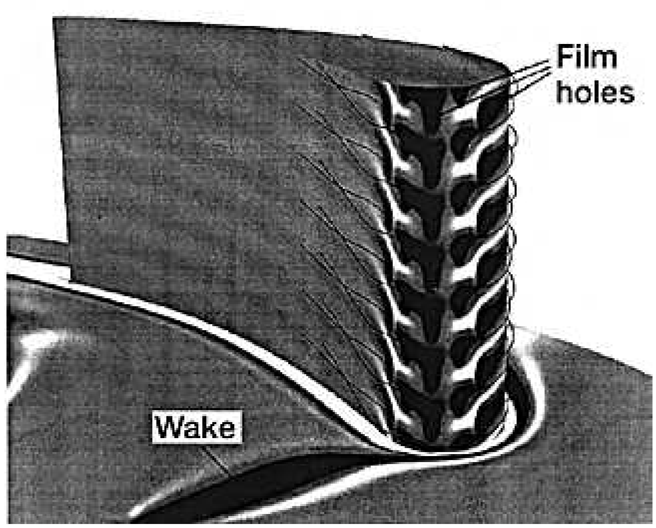
Effects of Rotor Wake on Film Cooling Investigated





Top: Rotor-wake facility. Bottom: Computed blade surface temperature and stream-surface entropy.

Through a combination of experimental and computational studies, researchers at the NASA Lewis Research Center investigated the effect of upstream blade-row wake passing on the showerhead (leading edge) film cooling of a downstream turbine. The experiments were performed in a steady-flow annular turbine cascade facility equipped with an upstream rotating row of cylindrical rods to produce a periodic wake field similar to that

found in an actual turbine. Spanwise, chordwise, and temporal resolution of the blade surface temperature were achieved through the use of an array of nickel thin-film surface gauges covering one unit cell of a showerhead film hole pattern. Film effectiveness and Nusselt numbers were determined for a test matrix of various injectants, injectant blowing ratios, and wake Strouhal numbers (*St*).

Results indicate a demonstrable reduction in film effectiveness with increasing Strouhal number, as well as the expected increase in film effectiveness with blowing ratio. An equation was developed to correlate the span-average film effectiveness data. The primary effect of wake unsteadiness was found to be correlated well by a chordwise-constant decrement of 0.094 *St*. Measurable spanwise film effectiveness variations were found near the showerhead region, but meaningful unsteady variations and downstream spanwise variations were not found. Nusselt numbers were less sensitive to wake and injection changes.

Computations were performed with a three-dimensional turbulent Navier-Stokes code that had been modified to model wake passing and film cooling. Unsteady computations were found to agree well with steady computations when the proper time-average blowing ratio and pressure/suction surface flow split were matched. The remaining differences were found to be due to enhanced mixing in the unsteady solution caused by the wake sweeping normally on the pressure surface. Steady computations were found to be in excellent agreement with experimental Nusselt numbers but to overpredict experimental film effectiveness values. This is likely due to the inability of the code to match actual hole exit-velocity profiles and the absence of a credible turbulence model for film cooling.

Bibliography

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